

NEW APPLICATION

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**BUILDING MATERIALS FROM NEEDLE-PUNCHED FIBER MATS  
WITH GRANULAR HEAT-ACTIVATED ADHESIVES**

**PRIORITY CLAIM**

This application claims priority under 35 USC 120(e) based on U.S. provisional application 60/408,946, filed on September 7, 2002.

**BACKGROUND OF THE INVENTION**

This invention relates to solid materials handling and to chemical adhesives, and discloses methods for converting needle-punched fiber mats (from sources such as shredded recycled carpets) into waterproof building materials, such as substitutes for plywood, roofing shingles, etc.

A method for creating sheets of wood-like materials, comparable to plywood but essentially waterproof and bug-proof, using nylon fibers obtained from shredded discarded carpet segments, is described in published PCT application WO 01/76869 (arising from PCT/US01/11895), by Forrest Bacon et al, the same Applicants herein. The contents of that published application are hereby incorporated by reference, as though set forth fully herein.

The above-cited PCT application describes a new use for needle-punched fiber mats. Those types of needle-punched mats, which have been made for years, are manufactured by a series of steps that include the following:

- a. segments of discarded carpet are shredded, using a rotating claw cylinder, to create a mass of rough yarn material;
- b. the rough yarn material is then combed and pulled apart, to create a relatively light and fluffy mass of nylon fibers;
- c. the fiber mass is combed into large continuous ribbons

roughly two feet wide and an inch or more thick;

d. machines called "cross-lappers" are used to deposit these ribbons transversely, across a slow-moving conveyor system (which typically is 13 feet wide, in order to make fiber mats that can be side-trimmed to exactly 12 feet wide); after the ribbons from several cross-lapper machines (typically, four machines are used in series) have been deposited onto the conveyor system, the resulting mass of fibers that rests on top of the travelling conveyor is more than a foot thick, with low density, and with essentially all fibers laying in roughly horizontal directions;

e. the thick mass is compressed to roughly 1/2 inch thickness, by compression rollers, to form a fibrous mat;

f. the fibrous mat passes through a needle-punch machine, which contains a wide steel "platen" with thousands of long needles having small nicks or barbs on the surfaces of their shafts;

g. the platen and the barbed needles are hammered against the mat, about 5 times per second, as the mat passes slowly through the needle-punching zone;

h. the barbs on the shafts of the needles grab individual fibers in the mat, and yank those fibers both upward and downward.

When the mat emerges from the needle-punch machine, it is strong and cohesive, and cannot be pulled apart by hand without great effort, because of the dense intertwining of the fibers. If the needle-punching operation is carried out properly, with a combination of plate width and conveyor speed that establish a sustained "dwell time" in the needle-punching zone, multiple thousands of fibers per square yard will be yanked into a "vertical" (transverse) position. As a result, a needle-punched mat made from recycled carpets has the general shape, feel, and flexibility of an extra-thick woolen blanket, and it is held together entirely by the fibers within the mat, with no need for expensive chemical adhesives.

In the past, these types of mats have been used mainly for two purposes: (i) as underlayments (also called pads, cushions,

etc.) for carpets installed in high-traffic areas, such as in stores, office buildings, theaters, etc; and, (ii) as padding and sound insulation in vehicles, such as in automobile trunks. However, there is not a high level of demand for these mats, since those uses are limited, and people generally prefer to have rubbery foam underlayers, which provide a spring-like bouncy feel, installed beneath carpets in homes and apartments.

PCT application WO 01/76869 describes an entirely new and different use for these types of needle-punched mats. In this new use, a liquid adhesive is spread between two or more mats, and the mats are then compressed against each other, using high pressures to drive the adhesive throughout the entire thickness of both (or all) mats. This process can be aided by using a two-component adhesive mixture that undergoes a chemical reaction that releases millions of tiny gas bubbles, soon after the two components are mixed together; the formation and release of the gas helps drive the liquid adhesive throughout the entire thickness of both of the dense fibrous mats that are being compressed against each other. One such subclass of adhesives includes specialized types of poly-alcohol resins that can be mixed with cyanate catalysts, to form polyurethane adhesives. In one example of a manufacturing operation, the two liquids can be mixed together, using a mixing nozzle, immediately before the resulting liquid mixture is spread across the juncture where two needle-punched mats will be compressed against each other, by rollers. The mats will then be held against each other, under pressure until the adhesive sets and hardens; this can be done by using a "moving belt press", of the type that is commonly used to manufacture plywood, oriented strand board, particle board, and similar types of materials, generally referred to herein as "sheetwood" materials to distinguish them from planks and other forms of sawed lumber.

The resulting material, which contains needle-punched mat(s) that have been thoroughly impregnated with hardened adhesive, has a stiffness, hardness, and "workability" (i.e., it can be sawed, drilled, etc.) that are comparable to plywood, oriented-strand

board, etc. However, the stiffened fiber-and-adhesive materials can be substantially stronger and more resilient than wood, and are also essentially waterproof and bugproof.

The main drawback and limitation of this manufacturing process is that two-component adhesives which will release gas bubbles, after being mixed together, tend to be expensive, and make up the large majority of the total cost of manufacturing these types of boards. Even when the total costs of collecting, shredding, combing, cross-lapping, and needle-punching discarded carpet segments are factored in, the purchase price of the adhesive is likely to be roughly 70 to 80 percent of the total cost of the final material. However, in the tests that were carried out prior to this invention, less expensive types of adhesives were not able to provide the consistency and uniformity that will be required to achieve widespread acceptance and commercialization of these types of wood-substitute materials.

The primary obstacle that prevented the successful use of inexpensive adhesives, prior to this invention, was the difficulty that was encountered in getting candidate adhesives to somehow permeate, diffuse, or otherwise be distributed in an even, consistent, uniform, and reliable manner, throughout the entire thickness of a needle-punched fiber mat. As anyone who has personally inspected a needle-punched mat made from shredded carpets can attest, the thickness and density of the mat, combined with the dense and complex intertwining of the fibrous matrix in the mat, poses a formidable and daunting challenge to any attempt to successfully drive any form of liquid, granular, or powdered material through the mat, in an even, consistent, and uniform manner.

This poses a major challenge, since evenness, consistency, and uniformity are essential to sheetwood materials that must compete against plywood or OSB. If even a single small seam fibrous mat material, which did not receive enough adhesive to harden properly, is present in a sheet of a plywood substitute, then that entire sheet will be unreliable and even dangerous to use in a building; it will be effectively worthless, since its

sale might subject the seller to large legal liabilities if it is incorporated into a building and then subsequently fails, due to the one small seam.

Nevertheless, the Applicant herein has developed a new method of creating sheetwood substitutes and other building materials, from needle-punched fiber mats, using granular adhesives. The crucial step in this invention centered on creating and developing a method for distributing a granular adhesive throughout the thickness of the fiber mat while it is being formed by the cross-lapper machines and the conveyor system, before the mat reaches the needle-punch machine.

Therefore, this new method of manufacture enables the selection and use of lower-cost granular adhesives, which fall within a class that is referred to within the industry as "hot melt" adhesives.

Accordingly, one object of this invention is to disclose a method of distributing and embedding heat-activated adhesives, in granular, powdered, or similar form, throughout the thickness of a needle-punched fiber mat, to render the mat useful for manufacturing a plywood substitute or other building material.

Another object of this invention is to disclose a method of using low-cost "hot melt" adhesives, during the manufacture of plywood substitutes and other building materials from needle-punched fiber mats.

Another object of this invention is to disclose plywood substitutes and other building materials, which contain needle-punched fiber mats that are held together and stiffened by means of granular or other low-cost "hot melt" adhesives.

Another object of this invention is to disclose the use of spun fiberglass, virgin nylon fibers, or other fibrous materials, to manufacture exceptionally strong, hard, waterproof, durable, and otherwise highly useful building materials.

These and other objects of the invention will become more apparent through the following summary, drawings, and detailed description.

### SUMMARY OF THE INVENTION

This invention discloses methods and machines for manufacturing building materials (including sheets of wood-like material comparable to plywood), using particulate adhesives that are embedded and distributed within needle-punched fiber mats. This manufacturing process uses the same types of cross-lapping and conveyor machines that are used to manufacture conventional needle-punched fiber mats, of the type that are widely used as carpet underlayers in commercial sites such as stores and restaurants. However, during the cross-lapping operation, and before a needle-punch operation is carried out on the mass of fibers that has been laid on top of the conveyor, one or more layers of particulate adhesives (which normally will be granular, in small pellets, etc.) are deposited and embedded into the large combed-fiber ribbons that are being laid across the conveyor. This can be done in any of several ways, such as: (i) by using one or more additional cross-lapping machines (which can be positioned on the opposite side of the conveyor system from the fiber-handling cross-lapping machines) to deposit one or more layers of granular adhesive onto or into the growing mass of fibers that is being deposited onto the conveyor; (ii) by sprinkling a granular adhesive across the upper surface of each large fiber ribbon as it leaves a combing machine and travels toward the cross-lapper head that is travelling back and forth over the conveyor; (iii) using one or more granular conveyors (such as moving belts, etc.) to continuously deliver granular adhesives to distributing devices, such as shaker trays or dimpled rollers that are mounted over the conveyor (presumably positioned between cross-lapper heads) to sprinkle a steady supply of the granular adhesive on top of the fiber mass that is being formed on the conveyor. Alternately or additionally, an inexpensive "hot melt" adhesive in a fibrous, stranded, or other form can be treated like shredded nylon fibers, incorporated directly into (or laid across the top surface of) the large combed-fiber ribbons that are being handled by the cross-lapper machines.

In addition, if desired, layers of adhesive material (in powdered, fibrous, or stranded form, continuous thin sheets, etc.) and/or polymers with low melting temperatures (such as polypropylene or other polyolefins) also can be laid on either side (top and/or bottom) of the mass of fibers that is being formed into a mat that will be needle-punched.

This type of adhesive deposition, carried out on the same conveyor system that is being used to create the thick mass of nylon fibers that will be compressed and then needle-punched, can distribute and embed a "hot melt" adhesive throughout essentially the entire thickness (or any targeted portion thereof) of a needle-punched fiber mat, regardless of how thick or heavy the needle-punched mat will be. The resulting mats are highly stable, and can be stored for months before the heated compression step.

When the needle-punched mat containing the hot-melt adhesive is passed through a heated press, the adhesive will melt into a highly sticky liquid that will be distributed throughout the entire thickness of the mat. This can generate a hardened wood-like material with a high level of consistency, uniformity, and strength. Accordingly, by allowing a manufacturer to eliminate the need for expensive two-component liquid adhesives that will release gas bubbles shortly after the two components are mixed, this method can reduce the total costs of the building materials that are being manufactured.

#### **BRIEF DESCRIPTION OF THE DRAWINGS**

FIGURES 1 and 2, which are prior art, depict the top and side views of a conveyor system that has four cross-lapper machines. Each cross-lapper deposits a continuous ribbon, made of combed nylon fibers, across the conveyor, which is moving from right to left in the drawings. These ribbons create a large and thick mass of fluffy material, which is then compressed by rollers and passed through a needle-punch machine. These systems have been used for years to manufacture needle-punched fiber mats, for use as carpet underlayers and as insulation in automobile trunks.

FIGURE 3 depicts a shaker tray for dispersing particulate adhesives, positioned adjacent to the rails that support a cross-lapper head that travels above a conveyor system as shown in FIGS. 1 and 2.

FIGURE 4 is a perspective cutaway view depicting a dimpled roller device for dispersing particulate adhesives.

#### **DETAILED DESCRIPTION**

As summarized above, this invention discloses methods and devices for embedding and distributing particulate adhesives within needle-punched fiber mats. This can allow the use of relatively inexpensive adhesives in the manufacture of various types of building materials (including sheets of wood-like material, comparable to plywood, as disclosed in published PCT application WO 01/76869, as well as various other types of building material (such as roofing shingles, embossed layers, laminated beams, etc.) that can be made from recycled carpets or other synthetic fibers.

This manufacturing process uses the same types of cross-lapping and conveyor machines that are used to manufacture conventional needle-punched fiber mats, of the type that are widely used as carpet underlayers in commercial sites such as stores and restaurants. A conventional system of this type, which is prior art, is shown as system 200 in FIG. 1 (a top or plan view) and FIG. 2 (a side or elevation view). These two figures are formal version of the informal drawings that were filed as FIGS. 4 and 5 in PCT application WO 01/76869, and the callout numbers have not been changed. Additional information on those types of conveyor and cross-lapper machines is provided in PCT application WO 01/76869, the contents of which are incorporated herein by reference, as though fully set forth herein.

In system 200, a set of four garnett machines 240 (also referred to as machines 242 through 248) is shown next to a conveyor belt 230. As conveyor belt 230 moves forward, each garnett machine continuously receives a load of fiber through an inlet (represented by inlet 243, on top of garnett machine 242).



Inside each garnett machine, the fiber is combed and pulled, in a manner that opens the fiber into a wide, flat ribbon that emerges from the garnett machine. Each ribbon enters a cross-lapping device; cross-lapper 250 (described in more detail below) distributes the output from garnett machine 242, while cross-lappers 262, 264, and 266 distribute the outputs from garnett machines 244, 246, and 248, respectively.

One component of each cross-lapping device travels back and forth across the main axis of the conveyor belt 230. This component, indicated by callout arrow 250, can be referred to by terms such as the operating head, the travelling head, the output unit, etc.; alternately, that travelling component can be referred to as the cross-lapping device, and the supporting rails and driving system can be regarded as just supporting devices.

An exemplary cross-lapper head 250 is illustrated in more detail in FIG. 3. It typically comprises a rectangular device that rides on four wheels 251. Wheels 251 typically have concave rounded pulley shapes, so that they will travel securely on parallel tubular rails 253, which usually are made of stainless steel or a similar smooth material. Cross-lapper heads are typically powered by chain drives, to ensure exact travel speed and placement with no risk of slippage as would occur with belts. A ribbon of combed fiber 255 is also shown in FIG. 3, being carried by the cross-lapper head 250 until it is deposited onto the conveyor 230.

The recipricating and cyclical motion of cross-lapper 250, back and forth across the conveyor 230, is referred to herein as "transverse" motion, and is shown by the directional arrows superimposed on each travelling head in FIG. 1.

As shown by the directional arrows, conveyor 230 is travelling toward the left, in FIGS. 1 and 2. As depicted in the side view shown in FIG. 2, conveyor 230 is empty as it begins to pass in front of garnett machine 242. Each garnett and cross-lapper combination deposits a thick ribbon of low-density fiber on top of the conveyor 230, thereby forming an uncompressed mat 210, which continues to grow thicker as it moves closer to the

compression rollers 270 and the needle-punch machine 300. As the uncompressed mat 210 reaches end roller 231, the mat 210 is lifted off of conveyor belt 230 by the compression rollers 270. The belt 232 travels downward around end roller 231, and returns to garnett machine 242, empty and ready to start another cycle.

The first garnett machine 242 and the first cross-lapper 250, working together, lay down a first ribbon of low-density fiber, shown by dashed lines in FIG. 1, which (for the first ribbon) are identified by callout arrow 259, which points to its "leading" edge, and callout arrow 260, which points to its "trailing" edge. Because the conveyor belt 230 moves steadily forward while the cross-lappers each move back and forth across belt 230, each ribbon being laid down by each cross-lapper will be deposited in an angled manner. As shown by the first ribbon, a first angle (shown by leading edge 259) is created while cross-lapper 250 moves away from garnett machine 242 and travels toward far (distal) position 256, and a second angle (shown by trailing edge 260) is created while the cross-lapper 250 returns to its near (proximal) position 258.

As indicated by the increasing density of the dashed lines in FIG. 1, and by the increasing thickness of uncompressed mat 210 shown from the side in FIG. 2, fibrous mat 210 grows substantially thicker as it passes in front of each garnett machine. In testing operations that created high-quality wood substitute materials, an uncompressed fibrous mat created by four garnett machines in series averaged about 12 inches (about 30 cm) or slightly higher, in thickness, before it entered the compression rollers.

As it reaches the end of the conveyor belt 230, the uncompressed mat 210 enters one or more compression rollers 270. These rollers flatten the uncompressed mat 210 into a relatively uniform desired thickness, such as about 1/2 to 1 inch thick. This material is shown as compressed sheet 275. To minimize shear forces and other potential tearing stresses on the mat, which does not yet have any form of reinforcement, it is generally preferable to use two or more sets of paired compression rollers,

mounted above and below the mat.

The compressed mat 275 enters needle-punch machine 300. This machine comprises a reciprocating drive mechanism, such as an arm 302 with one end mounted on a rotating wheel 304, driven by electric motor 306. Arm 302 is coupled to needle platen 310, which has thousands of needles 312 exposed on its bottom surface, in a regular geometric array. As mentioned in the Background section, each needle has a number of barbs or nicks, on the portion of the needle shaft that will pass back and forth through the compressed mat 275. Accordingly, as wheel 304 rotates, typically at a rate of about 5 cycles per second, the entire set of barbed needles 312 is repeatedly forced down through the compressed mat 275, and then lifted up again. To facilitate the needle-punching operation, the mat 275 passes across a supporting anvil 320 which is provided with a relatively narrow trough, directly beneath the needle zone, to accommodate the needle tips that emerge through the bottom of the mat.

As the needle-punching process is carried out, the barbs on the needle shafts will pull thousands of fibers both upward and downward, in each square yard of the mat. This substantially increases the cohesive strength of the fiber mat, and creates a needle-punched mat 350. This mat 350 can also be regarded as having an "interwoven" or "interlaced" matrix or lattice. The combination of (i) fibers oriented in different directions, and (ii) open pore spaces that were created or enlarged by the needles and barbs during the punching process, help create what is believed to be an ideal porous structural matrix for subsequent processing as disclosed herein.

#### **DEVICES FOR DISPERSING PARTICULATE ADHESIVES**

During the cross-lapping operation, and before a needle-punch operation is carried out on the mass of fibers that has been laid on top of the conveyor, a substantial quantity of particulate adhesives (which will be in a form such as granules, flakes, small pellets, etc.) are deposited, embedded, or otherwise distributed into and through the uncompressed mat 210

that is being formed on top of the conveyor 230.

This can be done in any of several ways, depending on the type of particulates that are being dispersed. For example, if small and relatively hard pellets, or large irregular-shaped granules, are being dispersed, a shaker tray can be used, as shown schematically in FIG. 3. This system uses a relatively wide tray 510, having a flat bottom 512 with multiple outlet holes 514 (also called orifices, apertures, etc.) passing through it. If desired, a coarse screen 516 can be fitted into the bottom of the tray 510, and additional devices (such as a slidable sheet that can be used to close the outlet holes 514) can also be provided. Alternately, instead of providing outlet holes in the bottom of a tray, a shaker tray can be tilted in a controlled manner that will cause particulates to spill out over one side of the tray at a suitable rate, in a manner comparable to using a weir-type skimmer to control the amount of liquid that passes over a barrier.

Tray 510 is mounted in a non-rigid manner (depicted by springs 520 and 522) to a supporting member 524, which can be a beam, shaft, etc. A powered device is used to impart a vibrating, shaking, oscillating, orbital, or comparable motion to the tray 510, so that pellets, granules, or other particulates that have been loaded into the tray (this can be done by any suitable type of delivery system) will fall out of the tray in a more even, uniform, and distributed manner. The device shown in FIG. 3 comprises an electric motor 530 having an eccentric weight 532 mounted to a rotating shaft.

Shaker trays and pelleted adhesives are not ideal, from the viewpoint of either material handling, or consistent and uniform distribution of melted adhesive throughout the final hardened product. However, pelleted materials can be made inexpensively, and in very large quantities, by extrusion machinery, and they may be less expensive than adhesives made in powdered or small granular form, or in thin flakes. Accordingly, shaker trays should be recognized as one option, and can be evaluated for use with any particular type of adhesive.

If the particulate adhesive is in the form of a powder, small grains, or thin flakes, it likely will be preferable to use a dimpled roller system, rather than a shaker tray. This type of system is depicted, in a perspective cutaway view, in FIG. 4, as roller system 600. This system comprises a trough or tray 602, made of sheet metal or similar material, and preferably having a wide top, for easier loading, and to provide greater capacity and reduce the risk of inadvertently running out of adhesive. A cylindrical roller 610 with a large number of relatively small and shallow depressions 612 (generally called dimples) that have been molded or machined into its surface is positioned at the bottom of the tray, and it rotates when the device is in use. Two flexible flaps 614 and 616 (made of a rubberized or other elastomeric material) press against the sides of the roller 610, and prevent spillage of excess adhesive out of the tray.

The rubber flap 614 prevents adhesive granules from leaving tray 602, unless they have settled into one of the dimples 612 on roller 610 (this settling process occurs due to gravity, as the upper surface of the roller passes beneath the pile of adhesive granules 630, which is stacked up on top of the roller 610, in tray 602).

This type of mechanism is commonly used for dispersing particulates across a linear distance, because it provides a simple yet effective method for controlling the rate of output of the particulates. If a greater dispersion rate is desired, the speed of rotation of the roller 610 is increased; conversely, if lower dispersion rates are desired, the speed of rotation of the roller 610 is decreased.

Shaker trays and dimpled rollers are merely examples of devices that can be used to disperse particulate adhesives across the entire width of a conveyor system. Other useful devices and systems are known, and can be evaluated for use as described herein, with any particular type of particulate adhesive.

These types of particulate dispersion devices can be placed at any of numerous locations, in a conveyor system such as illustrated in FIGS. 1 and 2. As examples, three dispersion

units, each of which can span the entire width of the conveyor 230, can be placed between each of the four cross-lapper machines 242-248.

In addition, if desired, layers of adhesive material (in powdered, fibrous, or stranded form, continuous thin sheets, etc.) and/or polymers with low melting temperatures (such as polypropylene or other polyolefins) also can be laid on either side (top and/or bottom) of the mass of fibers that is being formed into a mat that will be needle-punched.

Alternately or additionally, an inexpensive "hot melt" adhesive in a fibrous, stranded, or comparable form, can be treated like shredded nylon fibers, allowing it to be incorporated directly into (or laid across the top surface of) the large combed-fiber ribbons that are being deposited on the conveyor by the cross-lapper machines.

It also should be noted that, by using embedded and distributed adhesives, new materials and devices that have modified surface (or "skin") layers, and discrete embedded layers made with heterogenous materials, can be manufactured.

#### **"HOT MELT" PARTICULATE ADHESIVES**

A broad variety of particulate adhesives are known, and any of them can be evaluated for use as disclosed herein. In general, the three factors that will require initial consideration, before proceeding further in any such evaluation, include:

(i) the cost of a candidate adhesive, which usually is expressed on a per-weight basis;

(ii) its melting temperature, which must be lower than the melting temperature of the nylon strands in the needle-punched fiber mats (if recycled carpet material is being used to create the fiber mats), and which generally will require lower heating costs if a lower melting temperature can be used;

(iii) its ability to adhere tightly to the type of fibers in the needle-punched mats (which generally will include nylon, with lesser quantities of polypropylene, if recycled carpet material is used to create the fiber mats).

Those items of information are well-known to any company that actively sells granular adhesives in large quantities, and various such companies can be located easily. Such companies include several large manufacturers, such as BASF, Georgia-Pacific, and the 3M Company, as well as numerous distributors.

Most types of particulate adhesives that are likely to be of interest and usually referred to within the industry as "hot melt" adhesives; this category distinguishes them from liquid adhesives that use solvents which will evaporate during curing. A number of major advances in hot-melt adhesives were created during the 1980's and 1990's, driven partly by concerns over the release of organic solvents into the atmosphere. As a result, an excellent overview of hot-melt adhesives is available from the Pacific Northwest Pollution Prevention Resource Center (PPRC), which has posted an outstanding compilation and review in its website, at <http://www.pprc.org/pprc/p2tech/hotmelt/hmintro.html>.

Very briefly, some of the more widely used subcategories of hot-melt adhesives include the following:

- a. EVA, which refers to ethylene-vinyl-acetate adhesives;
- b. SIS, which refers to styrene-isoprene-styrene adhesives;
- c. SBS, which refers to styrene-butadiene-styrene adhesives;
- d. APAO, which refers to amorphous poly-alpha-olefin adhesives;
- e. polyethylenes;
- f. polyamides (however, it should be noted that nylon is itself a polyamide, and the melting points of polyamide adhesives generally will render them either unusable for use with nylon fiber mats, or unnecessarily expensive, from the viewpoint of heating requirements);
- g. phenolics, including phenolic-formaldehyde compounds.

These is just a brief listing, and extensive additional information is available from sources such as the PPRC website (which provides a good introduction), and from vendor companies, who have technical specialists who are closely familiar with the details and the performance traits of the adhesives they sell.

Accordingly, any such particulate adhesive can be evaluated

for use as disclosed herein.

It must also be clearly and explicitly recognized that in any such evaluation, the details of the intended final product (including the exact type or mixture of fibers that will be used to make the needle-punched fiber mat that will be impregnated by the particulate adhesive) must be taken carefully into account. A wide variety of such building materials can be made by using adhesives to stiffen needle-punched mats, including (1) sheetwood substitutes, which can be used instead of materials such as plywood, OSB, particle board, paneling, siding, etc; (2) embossed materials with non-planar surfaces, such as shingle substitutes, adhesive backer boards, sheets with grooves that can be laid on top of freshly-laid concrete to allow moisture to escape from the concrete, etc; (3) laminated beams, which can be made with any desired thickness, width, and length, by gluing together layers that have been sawed into planks or comparable shapes; and, (4) other items (such as door thresholds, flooring transition strips, etc.) that would be more useful if from exceptionally strong, durable, and waterproof materials.

Any of these building materials can be made from nylon fibers obtained from recycled carpet segments (which can be either post-consumer waste, or never-washed-on "post-industrial" waste). Alternately, because the building materials that can be made from needle-punched fiber mats and adhesives have extraordinary performance traits, they can also be made from virgin nylon fibers, if desired, or from mixtures of virgin and recycled fibers.

In addition, still other types of fibers can be used, if desired. As just one example, the Applicant herein recently tested spun fiberglass strands, that were formed into a needle-punched mat and then impregnated with an adhesive that binds tightly to fiberglass. The resulting material was extraordinarily hard and strong, and was closer, in its physical and performance traits, to stainless steel, than to wood.

It should also be noted that needle-punched fiber mats that contain embedded particulate adhesives are highly stable, and can



be stored for months or possibly even years, before a heated compression treatment is used to manufacture them into final hardened products. Accordingly, adhesive-containing fiber mats can become a valuable item of commerce in their own right, as an article of manufacture, and are regarded as one embodiment of this invention.

In at least some situations, when fiber mats are being used that have high polypropylene contents, from shredded discarded carpet segments, it may be preferable to use an adhesive that has a lower melting or activation point than the melting point of polypropylene. This can provide at least one clear advantage, in terms of reduced energy requirements for both (i) heating any presses up to high temperatures, and (ii) adequately ventilating and cooling the building where the press is operating. It may also be able to provide one or more other advantages as well, in avoiding and eliminating the tendency of polypropylene to shrink and distort somewhat when it melts, which otherwise can require additional steps to ensure that shrinkage or distortion of the polypropylene will not cause warping or other distortion of a sheet of fibrous wood substitute.

It also should be noted that similar treatments, using adhesives, can be used to convert various other types of fibrous mats into substitutes for plywood, particle board, oriented-strand board (OSB) and other building materials. Examples of fibrous mats that can be evaluated for such use using no more than routine experimentation include fibrous mats that are often called "air-laid" or "bat-formed" by those familiar with this field of art.

It should also be recognized that, if adhesives are used which are embedded or otherwise distributed throughout the entire thickness of the fibrous mat before it is heat-treated or otherwise treated to activate the adhesive, then it can become practical and feasible to compress essentially any (reasonable) number of layers, each layer having essentially any thickness that is of genuine interest, into a final building material such as a plywood substitute. The final material will have a thickness

that will depend on the number and the thickness of the fibrous layers that were incorporated into the final material (this type of total fiber weight usually can be expressed in terms such as weight per square foot, square yard, or square meter, or in terms such as weight per sheet of material).

Thus, there has been described a new and improved approach to manufacturing building materials from needle-punched fiber mats, using particulate adhesives. Although this invention has been exemplified for purposes of description by reference to certain specific embodiments, it will be apparent to those skilled in the art that various modifications, alterations, and equivalents of the illustrated examples are possible.